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REMOTE SENSING AND FIELD EVALUATION OF WETLANDS IN THE SANDHILL--ETC(U)
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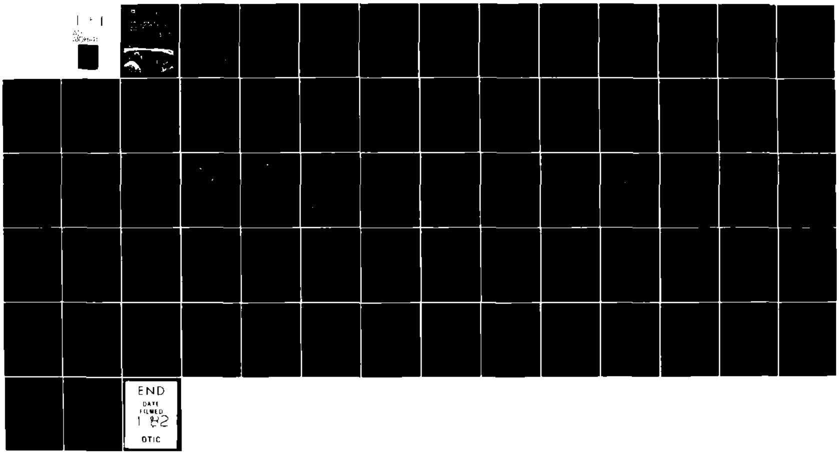

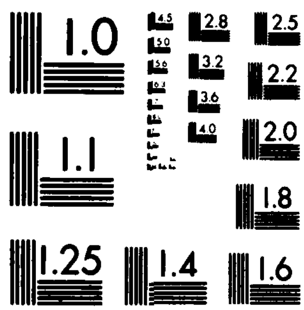

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REMOTE SENSING AND FIELD EVALUATION OF WETLANDS IN THE SANDHILLS OF NEBRASKA

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REMOTE SENSING AND FIELD EVALUATION
OF WETLANDS IN THE SANDHILLS
OF NEBRASKA

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

- INTRODUCTION -

Remote sensing data provides the primary source of wetland inventory information for application by various management or regulatory agencies. High altitude color infrared aerial photographs and Landsat derived products are the systems commonly applied for inventories of large areas. Vegetation types and detectable hydrological phenomena interpreted from such data provide the basis for identification of wetlands and their boundaries. Capabilities of the Landsat system have been demonstrated by LaPerriere and Morrow (1978) and Rundquist and Turner (1980) in wetland inventories in Alaska and the Northern Great Plains respectively. Nyc and Brooks (1979) and Montanari and Wilen (1978) describe techniques being used in the application of high altitude color infrared to the National Wetland Inventory Project.

With the production of remotely sensed wetland maps, various questions have been raised in regards to the accuracy of the wetlands delineated. These questions not only center around the resolution capabilities of a particular system, but also the expressed level of detail needed by legislative, regulatory, or management requirements in the user community. Various authors have addressed accuracy not only within a remote sensing system, but also in a comparison of different systems with known ground truth. Computer manipulation of digital data, data stratification, correction factors derived from satellite/aircraft double samples, layered classifiers, and multitemporal analysis have all been investigated. (Carter, Malone and Burbank, 1979; Gilmer, Colwell and Work, 1978; LaPerriere and Morrow, 1978; Owens and Meyer, 1978; Werth and Meyer, 1979).

Delineation problems exist not only from a remote sensing standpoint, but also from the perspective of delineating boundaries in the field within the context of the Corps' wetland definition. Most wetlands are bounded by a transitional area in which the wetland community grades to a mesophytic or xerophytic community. Other types of areas, such as seasonally flooded or meadow habitats, may or may not exhibit this gradation, rendering the questions to not only that of delineation, but also applicability as to wetland status. Criteria for delineating wetland boundaries or determining wetland status is not set forth in the Corps of Engineers permit regulations.

Within the context of these problems of accuracy and the lack of methodology for determining wetland boundaries and status, this study will apply remote sensing and field investigative techniques to wetland delineation and evaluation in the Sandhills of Nebraska. Accuracy of Landsat wetland mapping, currently in use by the Omaha District, will be addressed by comparisons with color infrared photography for an approximately 120 square mile area. Further analysis involves the delineation of a selected wetland community for comparisons with its depiction from remotely sensed data. Additional goals of this study are to analyze temporal change and determine if subirrigated meadows[1] can be properly classified as wetlands by virtue of their species composition or by comparisons with a known wetland community. For the purposes of this study, wetlands will be defined according to the Corps of Engineers permit regulations

[1]Subirrigated meadows are defined as areas where the root zone is in contact with the water table.

(33 CFR 323.2): "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

The Sandhills region of North Central Nebraska is the largest continuous area of sand-dune formation in the United States, consisting of approximately 20,000 square miles. Formed on a broad, sloping plain ranging from an elevation of approximately 4,000 feet at its western margin to 2,000 feet at the east, the Sandhills are believed to have been formed by major wind action during the early Wisconsinian glacial period. These dunes, laying over several layers of permeable rocks and clays, were later stabilized through climatic changes and the establishment of vegetation.

This vegetation, consisting predominantly of grasses, has received considerable attention and has been inventoried by a number of investigators (Smith, 1892; Rydberg, 1895; Pool, 1914; Tolstead, 1942). Though several additional studies have emphasized vegetative composition relationships to the hay production/cattle grazing industry (Frolik and Keim, 1933; Frolik and Shepherd, 1940; Brinegar and Keim, 1942; Bragg, 1978), little quantitative work has been done concerning transition zones between xeric-mesophytic-hydrophytic plant communities.

Rydberg (1895) recognized differences in sandhill plant communities by describing wet valley and dry valley associations. Pool (1914), however, appeared to be the first investigator to not only recognize such differences, but properly attribute this distribution of species to differences in soil moisture and their proximity to the

water table. Based partially on soil moisture content and duration, Pool desc𝑟ibed three distinct plant formations of sandhill lowlands (water-pl nt, marsh, and meadow) and ten sub-formations differentiated by dominant plants present. More specifically, Frolik and Keim (1933) outlined three grass associations in a study exemplifying variation in yield of native prairie hay as affected by depth of the ground-water table. Similarly, Tolstead (1942) described three zones of mesophytic tall grasses occurring in wet meadow regions based on the depth and permanence of the underground water table. Additionally, zonation within wetland areas was noted, though not quantified. Brinegar and Keim (1942) also noted a natural change in dominant grass species as one moved from lake edges to dry, upland sandhills.

None of these plant association/classification systems, however, would be adequate in delineating wetland from non-wetland areas or in determining the wetland status of subirrigated or wet meadows.

Change in Sandhill vegetative communities has been documented by various investigators. Pool (1914) indicated that climate may determine the relative abundance of species for different years. Tolstead (1942) discussed changes in hydric species composition, species dominants, and the invasion by mesic grasses throughout the meadow of Dewey Lake for a 4-year period as a result of drought and depletion of groundwater. The reduction of emergent aquatics accompanying high water was noted by Sather (1958) in his investigation of muskrat populations in the Sandhills. For a 3-year period from 1949 to 1951, Rice Lake increased from 33 to 51 acres with the emergent plant communities practically eliminated. However, little quantitative work has been done to document changes within a growing season for Sandhill wetland

communities.

A previous remote sensing investigation of wetlands in the Sandhills was conducted by Seevers et. al. (1974). The information was obtained from Landsat visual imagery. Wetlands ten acres or larger were delineated on U.S. Geological Survey topographic maps at a scale of 1:250,000. Wetlands were categorized into four classes; open water, marsh, subirrigated meadows and seasonally flooded basins. A more recent investigation involves that by Rundquist and Linden (1979). Selected areas of the Sandhills were evaluated with Landsat digital data and supplemented by medium and large scale color infrared. Capabilities of the Landsat system were demonstrated for identifying, mapping and evaluating temporal change in wetlands. An additional inventory of wetlands in the Sandhills is currently being undertaken as part of the National Wetland Inventory Project using the classification system described by Cowardin et. al. (1979).

More pertinent to this study is the work of McMurtrey et. al. (1972) in their survey of wetland areas in Nebraska. Basic data was acquired from interpretation of black and white Soil Conservation Service photographs supplemented by extensive ground data. This study specifically excluded the extensive acreages of wet meadows in the Sandhills, though such areas had been recognized as Type II wetlands (classification system, Circular 39, Shaw and Fredine, 1956). The survey concluded that determining those portions of the meadows wet enough to be acknowledged as wetlands would be "impractical."

- MATERIALS AND METHODS -

The Study Sites -

The study was conducted at the Valentine National Wildlife Refuge located in the Nebraska Sandhills. The approximately 70,000 acres of the Refuge is characterized largely as undulating sand dunes interspersed with lakes, wetlands, subirrigated meadows and dry valley complexes. Specific study sites are defined at two levels. Two 7.5 minute orthoquads, Simeon SE and SW, constitute the boundaries of the study area used for the evaluation of Landsat accuracy. Within these orthoquads, the wetland community of Rice Lake and the subirrigated meadows of Little Hay Valley and Watts Lake served as areas of intensive field work (Figure 1).

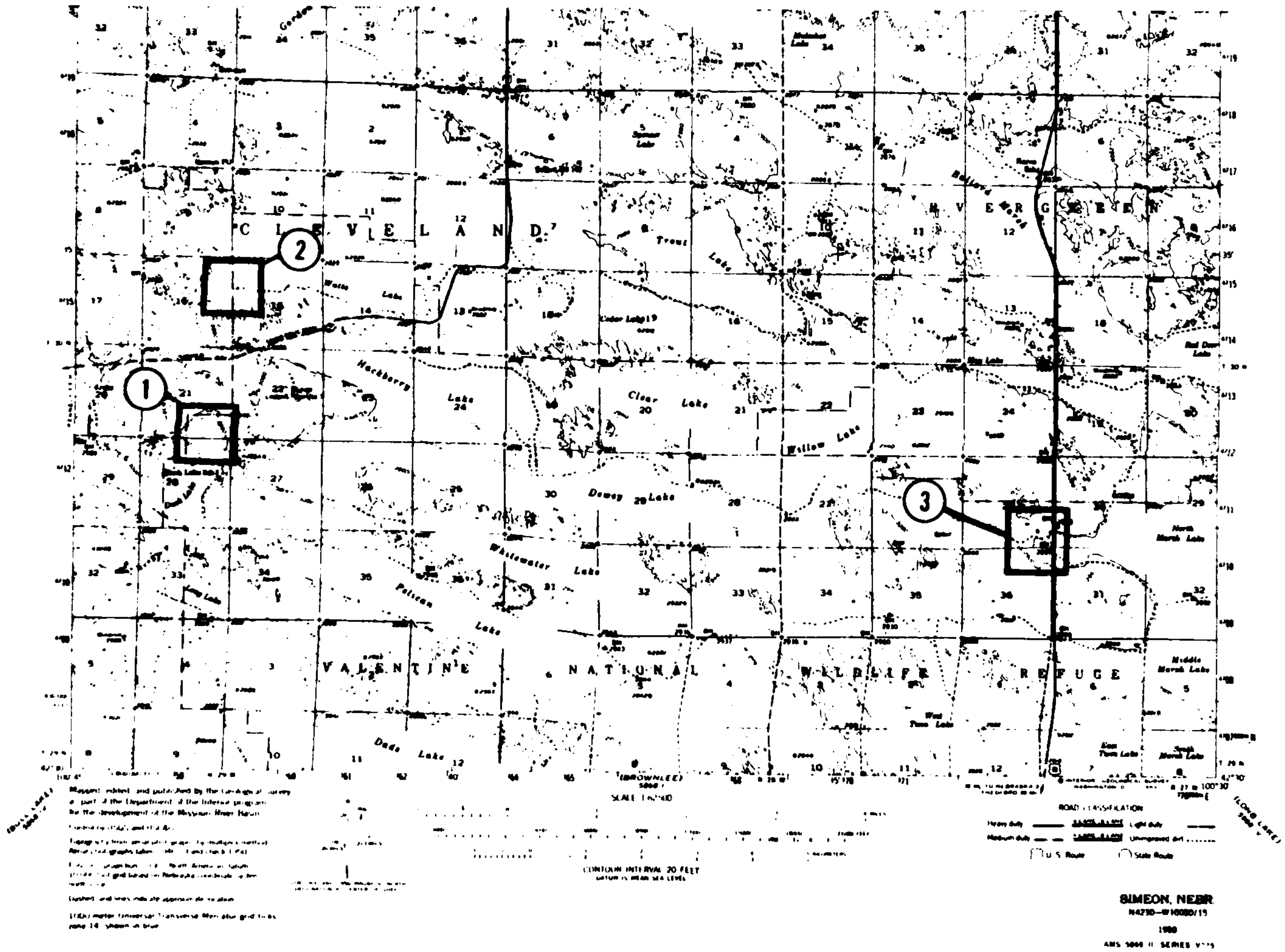


Figure 1. The study area; 1) Rice Lake, 2)subirrigated meadow of Watts Lake, 3) subirrigated meadow of Little Hay Valley.

Remote Sensing Systems -

Information from the Landsat 3 satellite was utilized for the study area. Landsat platforms contain two primary sensing systems, the Return Beam Vidicon (RBV) and the Multispectral Scanner (MSS). This research focuses on the digital data gathered by the MSS.

Data from the Landsat MSS sensor is recorded and then transmitted to earth receiving stations. This data is then electronically transformed into a photo-like image format and into computer compatible tapes (CCT's). The CCT's contain the digital data in a form capable of computer processing and analysis. Reflected solar energy received by the MSS sensor is recorded in four wave length bands of the electromagnetic spectrum, designated Bands 4, 5, 6, and 7.

Individual Landsat scenes produced by the MSS sensor and contained on the CCT's are 185 x 185 km (115 x 115 statute miles) in area. Each scene is composed of approximately 10.5 million picture elements per band. Each picture element, termed a pixel, is treated spatially as an area 57 x 57 m (approximately .8081 acre). A discrete reflectance value is assigned to each pixel based upon terrain features, atmospheric elements, and ground cover. This reflectance value is related to the spectral sensitivity of the MSS band in use. In the final format, CCT Bands 4, 5, and 6 have 128 discrete reflectance levels and Band 7 has 64 levels.

The September Landsat scene was acquired to correspond as closely as possible to the September date of the color infrared aerial photography and to the late August vegetation field study. The digital data contained on the CCT is nominally at a scale of 1:24,000, corresponding to that of the orthophoto quads used in this

evaluation. Computer processing was accomplished by single band level thresholding of the reflectance data. The thresholding was accomplished with the use of the UNO-RSAL "Looklot" program. The detection of wetlands and their classification was based upon comparisons of the reflectance values of wetlands in specific locations with known ground truth information (CIR photos, preexisting maps, etc.) Once the thresholds for both Bands 5 and 7 were established, two band parallelepiped classification was utilized for the actual mapping of the study area (Bussom and Rundquist, 1978; Work and Gilmer, 1976).

Nine by Nine inch color infrared was flown over the study area September 14 at a resulting scale of 1:24,000. A 35 mm color infrared underflight was accomplished concurrently with June and August fieldwork for Rice Lake and the subirrigated meadow study sites. Flightlines between these sites were established and photographs taken at selected intervals between 500 feet and 10,000 feet above ground level following procedures discussed by Meyer and Grumstrup (1978).

Remote Sensing Analysis -

Each of the two quadrangle overlay maps produced from the 9 x 9 inch colo: infrared photographs has three classes delineated; open water (O), marsh (M), and subirrigated meadow (S). These overlay maps represent what is considered to be the actual extent and configuration of the wetlands on the ground. The two overlays produced using the Landsat digital data had the same three classes delineated. The unclassified upland areas were grouped into the non-wetland classification in both systems. Both sets of maps (CIR and Landsat) were measured using an electronic planimeter.

The accuracy of the Landsat mapping system was based in part upon comparison of the acreage totals derived from the measurements. Further analysis of accuracy was accomplished using a $1cm^2$ grid overlay from which two separate point samples were taken.

The first sample of 140 points per map was taken to compare the accuracy of the Landsat system in terms of wetland versus non-wetland classification. For each point a determination was made as to the classification on the CIR map and the same point on the Landsat map. The Phi Coefficient (Ø) was used to test the relationship between the two mapping systems. The Phi Coefficient has a value of zero (0) when no relationship exists and the value of one (1) when the variables are perfectly related.

The accuracy of the Landsat system for the specific mapping classes (open water, marsh, subirrigated meadow, and non-wetland) was tested using a larger sample from the $1cm^2$ grid. A systematic stratified sample of 1120 points per quad was taken. As in the previous test of accuracy, the classification at each sample point on the CIR

map was compared with that point on the Landsat map. This sample provided an index in the form of a 4 x 4 matrix from which percentages for the various CIR-Landsat classification comparisons were derived.

Vegetation Sampling -

Initial work consisted of determining transect locations at the study sites. The end points of each transect were identified by ground markers of two strips of white opaque plastic approximately 2 feet wide by 15 feet long. The two strips were aligned in such a manner to form an X configuration. An additional 3 feet by 3 feet sheet of black plastic was placed beneath the intersection of the two strips for contrast purposes. Markers were constructed and placed so as to be visible on low altitude color infrared and to serve as locational aids in vegetative mapping. Three transects were placed at Rice Lake and one at Watts Lake on both the June and August sampling dates. One transect was located at Little Hay Valley on the June date only due to haying operations. Along each of the main transects, subtransects were located at either a right angle to the main transect or through the longitudinal axis of a homogenous vegetative zone. Ten $1m^2$ plots were located five on each side of the main transect at 2 meter intervals along the subtransect, alternating sides (Figure 2).

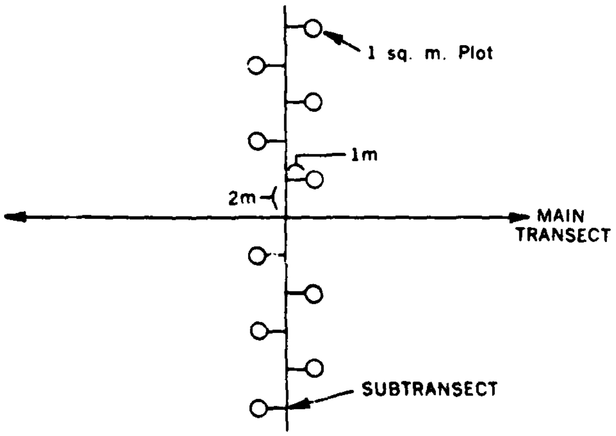


Figure 2. Schematic representation of transect, subtransect and plot locations.

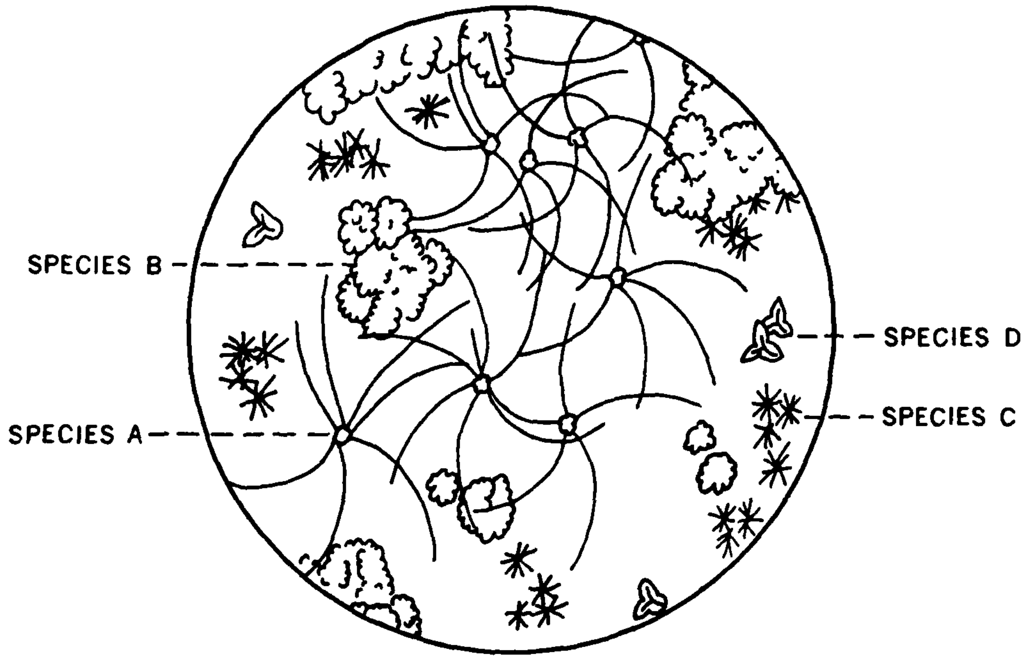
Ground sampling the $1m^2$ plots was accomplished utilizing a canopy-cover method of vegetational analysis (Daubenmire, 1959). Canopy area as used in this method is defined as the area parallel to the ground surface bounded by a line connecting the outermost extremeties of the plant. Because precise measurement can be extremely difficult and time consuming, it was more efficient to estimate cover utilizing the following classes:

Class Number	Class Range (%)	Class Midpoint (%)
1	0-5	2.5
2	5-25	15.0
3	25-50	37.5
4	50-75	62.5
5	75-95	85.0
6	95-100	97.5

Class midpoint values were used for analysis.

Canopy cover estimates for individual species within a hypothetical plot are shown in Figure 3.

In addition to cover estimates for each individual species occurring in a plot, general vegetative and community characteristics of each plot were also evaluated. This information was recorded in the field on data sheets for use in vegetative analysis (see Appendix A).



Species	Class Range	Class Number
A	50-75%	4
B	5-25%	2
C	5-25%	2
D	0-5%	1

Figure 3. Canopy cover estimates of a hypothetical plot.

Vegetation Analysis -

Information from the ten $1m^2$ plots located on a subtransect were combined to define a $10m^2$ sample area. Species information was then derived from the following calculations:

1) Frequency (f) - the number of plots in which a given species occurred divided by the ten plots of the subtransect.

2) Relative frequency (Rf) - the frequency (f) of a given species divided by the sum of the frequencies for all species which occurred in the subtransect.

3) Cover (c) - the summation of the number of plots in which a specific class number was recorded multiplied by that class numbers midpoint, divided by the ten plots of the subtransect (that is, the portion of the canopy occupied by an individual species within the $10m^2$ area of the subtransect).

4) Relative cover (Rc) - the cover (c) of a given species divided by the sum of the covers for all species which occurred in the subtransect.

5) Importance Value (IV) - the sum of the relative frequency (Rf) and the relative cover (Rc) for each individual species.

The importance value was utilized as an overall estimate of the influence or importance of an individual plant species in the total vegetative community. All species occurring in a subtransect were then ranked in order of decreasing importance value. In this manner, the dominant species for each subtransect were identified. Data for a selected subtransect is illustrated in Table 1.

TRANSECT 3 SUBTRANSECT 01

SPECIES	FREQUENCY	RELATIVE FREQUENCY	COVER	RELATIVE COVER	IMPORTANCE VALUE	RANK
Carex 8	0.70	0.1346	21.8	0.2759	0.41056	1
Juncus balticus	0.70	0.1346	19.7	0.2494	0.38398	2
Panicum virgatum	0.40	0.0769	15.4	0.1949	0.27186	3
Rosa arkansana	0.70	0.1346	2.7	0.0342	0.16879	4
Poa pratensis	0.40	0.0769	7.0	0.0886	0.16553	5
Artemesia ludoviciana	0.50	0.0962	4.9	0.0620	0.15818	6
Ambrosia psilostachya	0.60	0.1154	1.2	0.0152	0.13057	7
Solidago sp.1	0.30	0.0577	3.2	0.0405	0.09820	8
Carex 10	0.20	0.0385	1.7	0.0215	0.05998	9
Panicum oligosanthes	0.20	0.0385	0.4	0.0051	0.04352	10
Glycyrrhiza lepidota	0.20	0.0385	0.4	0.0051	0.04352	11
Equisetum laevigatum	0.20	0.0385	0.4	0.0051	0.04352	12
Apocynum sibiricum	0.10	0.0192	0.2	0.0025	0.02176	13
TOTALS	5.20	1.0000	79.0	1.0000	2.00000	

Table 1. Data for a selected subtransect.

Importance values were also utilized to derive an index of species diversity or community structure for each subtransect. Evaluation of community structure was initiated by calculating the Simpson Dominance Index (λ):

$$= \frac{\Sigma\, n_i(n_i-1)}{N(N-1)}$$

where n_i = the IV of each individual species, and

N = Σ of importance values for all species in the subtransect.

The Simpson Dominance Index (λ), simply expressed, is the probability of two individuals selected at random from a subtransect belonging to the same species. A subtransect exhibiting low dominance will exhibit high species diversity. Accordingly, diversity was measured utilizing the Simpson Diversity Index (D_s):

$$D_s = 1 - \lambda$$

D_s values express the probability of one species in the subtransect encountering an individual of another species.

Community similarity comparisons between selected subtransects were based on Morisita's Index (I_m). This measure of similarity is arithmetically related to λ as shown in the following:

$$I_m = \frac{2\Sigma\, x_i y_i}{(\lambda_1 + \lambda_2) N_1 N_2}$$

where $x_i y_i$ = product of importance values for species common to both subtransects

λ_1 = Simpson Dominance Index for subtransect 1

λ_2 = Simpson Dominance Index for subtransect 2

N_1 = Total of all IVs for subtransect 1

N_2 = Total of all IVs for subtransect 2

Morisita's Index (I_m) expresses a relative probability of randomly drawing the same species from each of the two communities. I_m values may range from 0 (no similarity between subtransects) to approximately 1 (identical subtransects).

A second measure of community similarity, the Sorensen Community Coefficient (CC_s), was conducted for purposes of cross-date comparisons at Rice Lake only. CC_s values do not account for changes in species' relative cover, but provide information on species disappearance/replacement rates over time as given by the following:

$$CC_s = \frac{2c}{s_1 + s_2}$$

where s_1 = number of species in community 1

s_2 = number of species in community 2

c = number of species common to both communities

CC_s values may range from 0 (no species common to both communities) to 1.0 (all species common to both communities).

In addition to determining a species influence or dominance in the vegetative community through IVs, each species was assigned a numerical hydric rank ranging from 1 to 5. The ranking system was designed to reflect an individual species' preferred or optimal moisture conditions. Species restricted to very dry, xeric conditions were assigned a rank of 1, while species restricted to standing water or extremely saturated soils were assigned a 5. Species with extremely wide moisture preferences were considered mesic and assigned a rank of 3. Numerical rankings of 2 and 4 were assigned to those species which exhibited tendencies to prefer either xeric or hydric conditions respectively, but were not totally obligate to such

conditions. Numerical hydric ranks were designated for each species based on descriptions available from the literature. Individuals not identified to species were assigned a numerical hydric rank of 3 unless their location on a transect indicated a xeric or hydric preference.[2] A list of Species collected and their hydric rank is found in Appendix B.

The prevalence of vegetation adapted for hydric conditions at each subtransect was determined by adding IVs of species having identical numerical hydric rank. Grouped IVs were then divided by the sum of all IVs in the subtransect to derive a relative frequency for each numerical hydric group. Relative frequency values were then multiplied by their respective groups' hydric rank to derive a weighted mean. Weighted means were added and divided by 100 to arrive at a hydric value for the entire subtransect. Hydric values for subtransects range from 1 (xeric) to 5 (hydric) similar to numerical hydric rank for individual species. A hydric value greater than 3.0 indicates a hydric community (wetland) while values less than 3.0 indicate a xeric community (non-wetland). Table 2 illustrates the grouped data from Table 1 and the derived hydric value.

[2] In order to delineate a wetland and determine the wetland status of subirrigated meadows, the need to define both "vegetation typically adapted for life in saturated soil conditions" and "prevalence" (33 CFR 323.2) became apparent. Through the use of a hydric ranking system an individual species' applicability to the term "typically adapted" is quantified and formulates the basis for establishing prevalence.

A. Listing of Species by Similar Hydric Rank.

GROUPING TYPE	SPECIES NAME	IMPORTANCE VALUE
1	---	---
2	*Rosa arkansana*	.16879
	Artemesia ludoviciana	.15818
	Ambrosia psilostachya	.13057
3	*Carex 8*	.41056
	Panicum virgatum	.27186
	Poa pratensis	.16553
	Solidago sp. 1	.09820
	Carex 10	.05998
	Panicum oligosanthes	.04352
	Glycyrrhiza lepidota	.04352
	Apocynum sibiricum	.02176
4	*Juncus balticus*	.38398
	Equisetum laevigatum	.04352
5	---	---

B. Summary of Hydric Value Measures.

GROUPING TYPE	IMPORTANCE VALUE	RELATIVE FREQUENCY	WEIGHTED MEAN
1	0.0	0.0	0.0
2	0.45755	22.8773	45.755
3	1.11495	55.7473	167.242
4	0.42751	21.3754	85.502
5	0.0	0.0	0.0
TOTALS	2.00001	100.0000	298.499

Hydric Value = 2.98499

Table 2. Derivation of a hydric value for Table 1 data.

Hydric values were calculated for all subtransects in the June and August field work. This information was utilized to: 1) delineate and map the wetland of Rice Lake in combination with 35 mm color infrared, 2) aid in determining the wetland status of subirrigated meadows, and 3) aid in evaluating temporal change at Rice Lake.

For purposes of community comparison, subtransects for both June and August sample dates were grouped into ecologically similar zones based on hydric value and species composition. The Rice Lake subtransects were grouped into three zones (non-hydric, outer marsh and inner marsh) as shown in Table 3. A submerged aquatic zone was also recognized and mapped though no subtransects occurred in this deep marsh area. Subtransects occurring in subirrigated meadows of Watts Lake and Little Hay Valley were grouped into two zones, non-hydric and hydric.

	NON-HYDRIC Subtransects	OUTER MARSH Subtransects	INNER MARSH Subtransects
Transect 1	(6) 1, 2, 3, 11, 12, 13	(3) 4, 5, 10	(4) 6-9
Transect 2	(8) 1-4, 15-18	(3) 5-7	(7) 8-14
Transect 3	(6) 1, 4, 22-25	(10) 2, 3, 5-9, 19-21	(9) 10-18
Transect 6	(7) 1-4, 10-12	(3) 5, 6, 9	(2) 7, 8
Transect 7	(6) 1-4, 16, 17	(6) 5-7, 13-15	(5) 8-12
Transect 8	(9) 1-3, 5, 20-24	(8) 4, 6-9, 17-19	(7) 10-16

Table 3. Rice Lake subtransects occurring in ecologically similar zones.

Hydric value profiles were compared for Rice Lake and the subirrigated meadow. Similarity comparisons (I_m values) between ecologically similar zones of Rice Lake and the two subirrigated meadow sites were also conducted. In addition, cross-date comparisons of hydric value profiles, I_m, D_s, and CC_s values were made for ecologically similar zones for temporal analysis at Rice Lake.

- RESULTS AND DISCUSSION -

Landsat A :uracy -

The : curacy of the Landsat mapping system is summarized in Table 4 from the comparisons of Figures 4 and 5 to Figures 6 and 7. In the case of the open water and marsh mapping classes, the Landsat system under estimated the total area. The subirrigated meadow class was over estimated by the Landsat system. Total wetland area irrespective of class was 99.17%. Accuracy for wetlands vs nonwetland comparison using the Phi Coefficient indicates a strong relationship between the two systems. Accuracy by mapping class in percent shows a high percentage of duplicity in classification.

A. Mapping Accuracy as a Function of Acreage Totals.

	CIR	LANDSAT	ACREAGE OF LANDSAT AS % OF CIR
Open Water	5,377.93	4,859.94	90.38
Marsh	5,065.53	4,837.03	95.49
Subirrigated Meadow	17,884.29	18,395.85	102.80
TOTAL	28,327.75	28,092.82	99.17

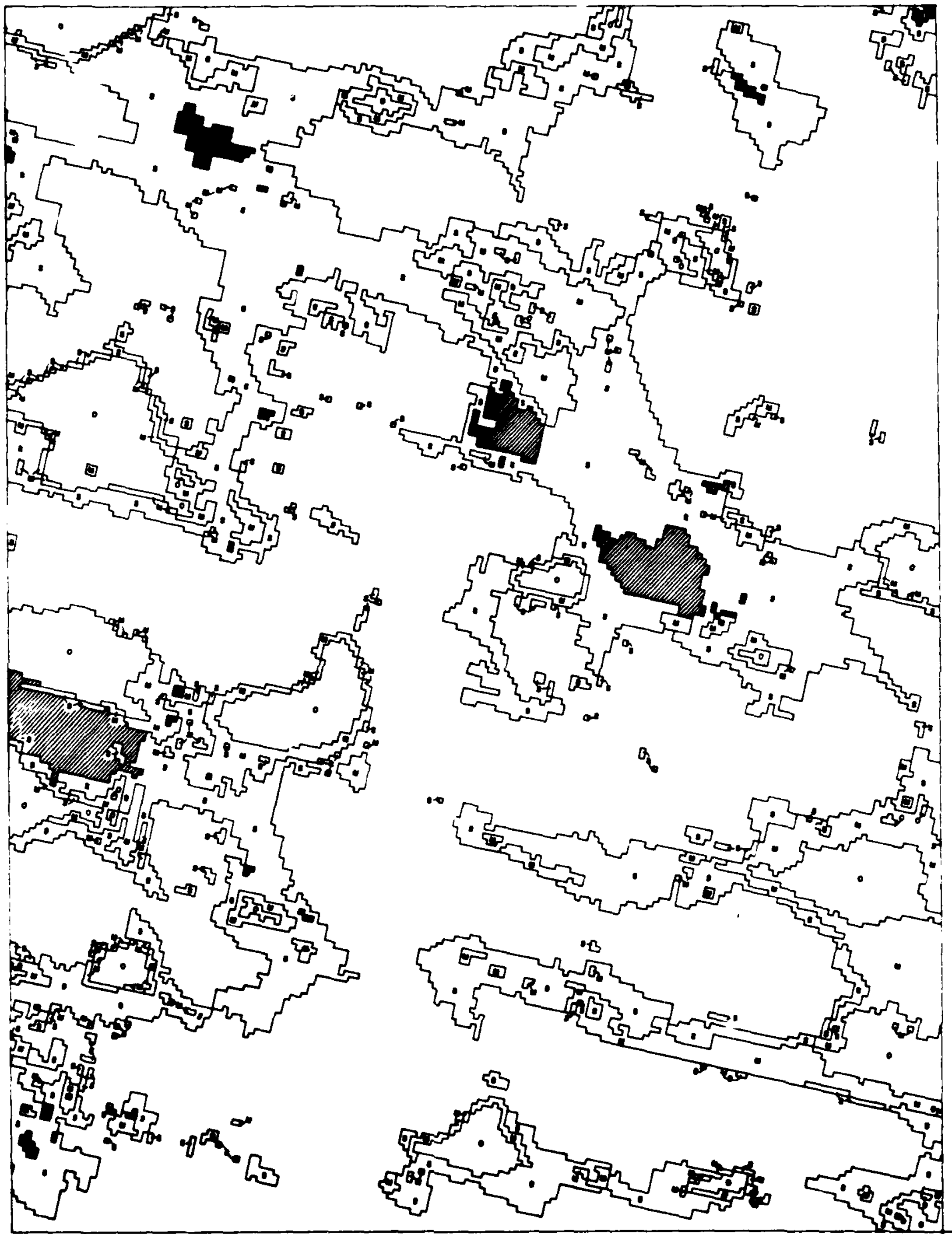
B. Mapping Accuracy as Expressed by the Phi Coefficient (Ø).

Ø = .8926

C. Classification Accuracy (%). Sample Significant at .005 Confidence Level.

LANDSAT \ CIR	OPEN WATER	MARSH	SUBIRRIGATED MEADOW	NON WETLAND
Open Water	93.15	0.00	0.00	0.00
Marsh	6.16	82.75	1.43	0.22
Subirrigated Meadow	0.00	16.66	90.29	2.98
Nonwetland	0.69	0.59	8.28	96.80
TOTAL	100.00	100.00	100.00	100.00

Table 4. Landsat accuracy results for Simeon SE&SW combined.



SIMEON SE, NEBR.

O = 2573,35
M = 2775,86
S = 8157,55

Figure 4. Landsat depiction of Simeon SE.

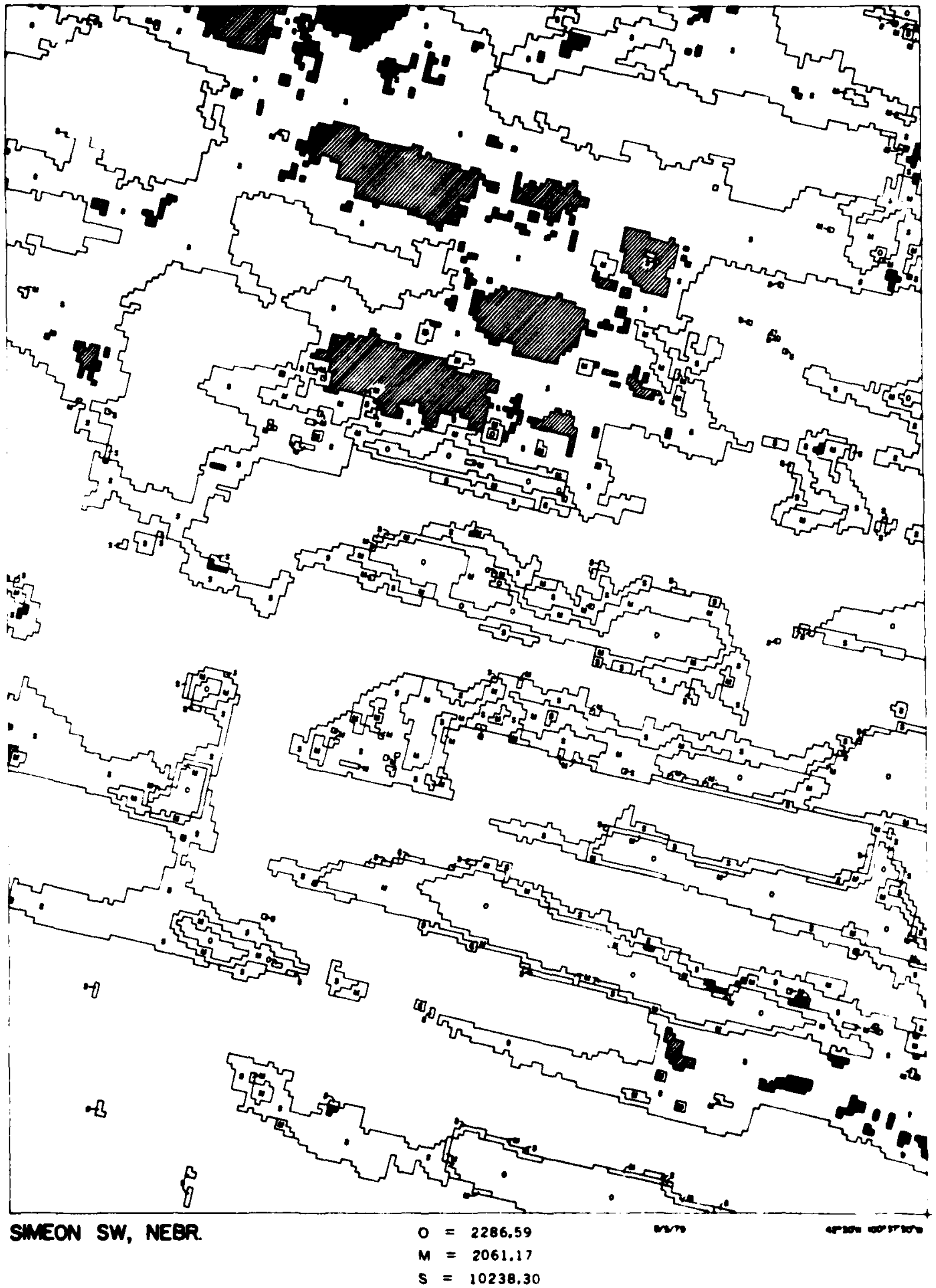


Figure 5. Landsat depiction of Simeon SW.

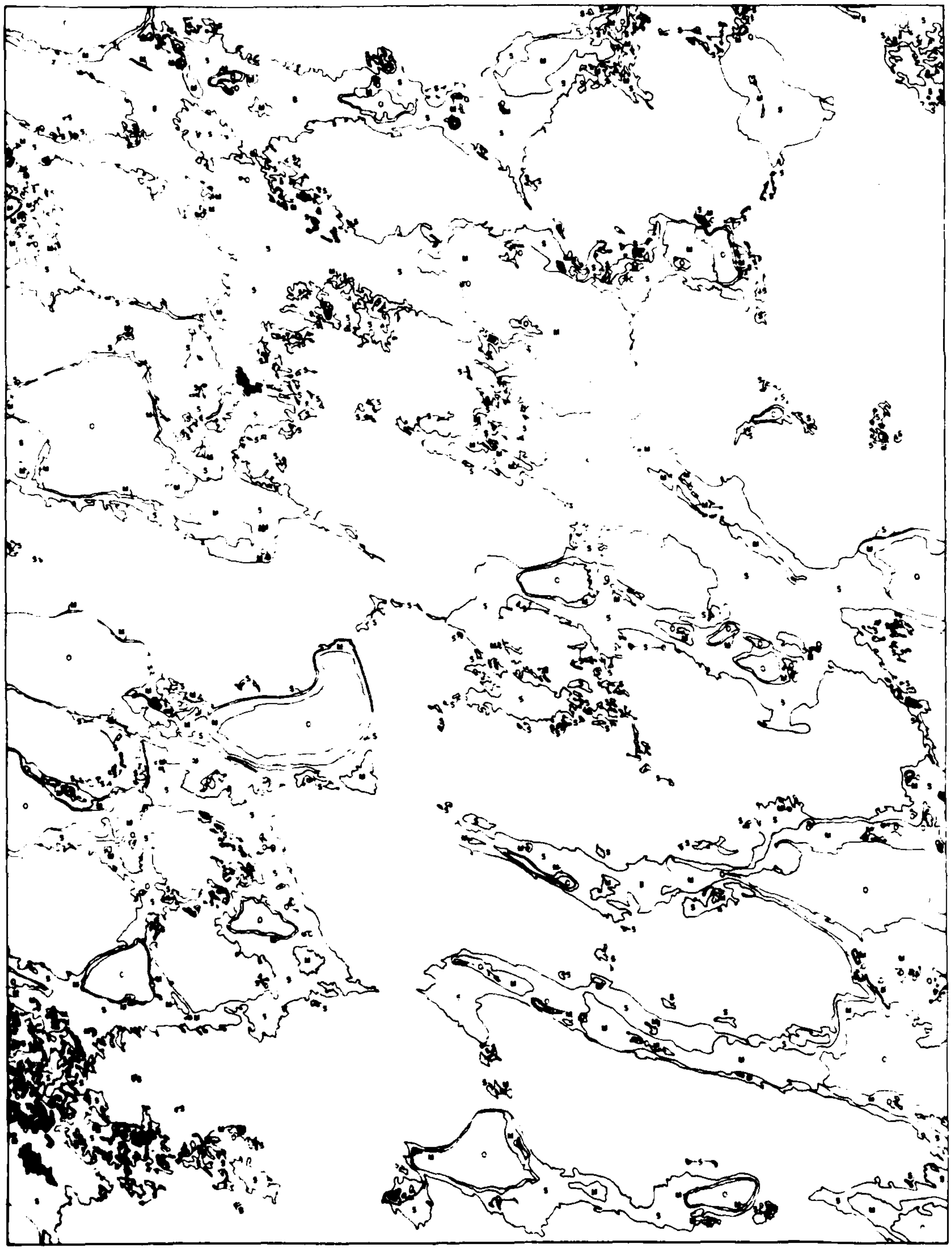


Figure 6. Color infrared depiction of Simeon SE.

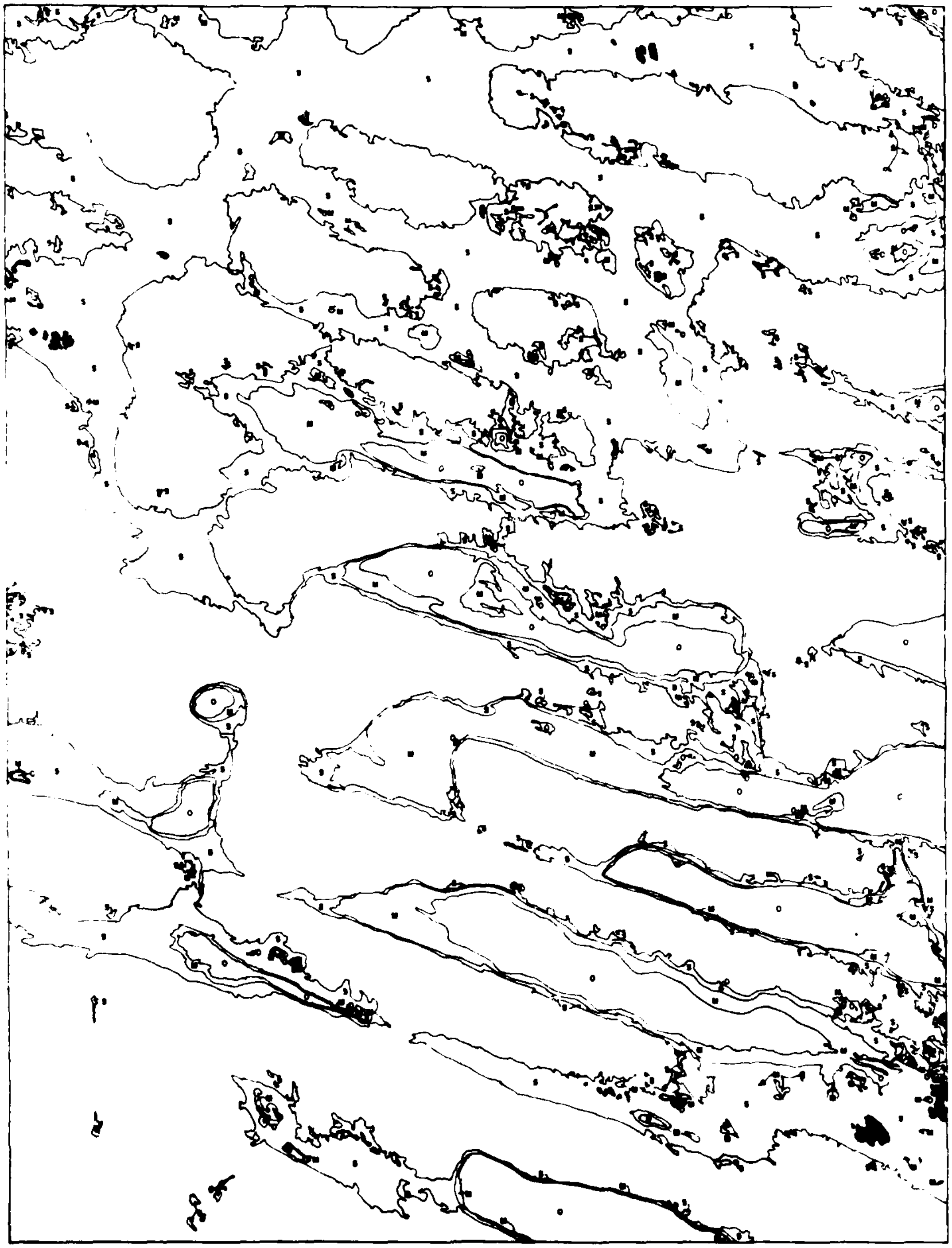


Figure 7. Color infrared depiction of Simeon SW.

When attempting to make a quantitative comparison of the two mapping systems used in this study, the resolutional capabilities of each of the systems must be considered. With the CIR mapping system it is possible to delineate very small areas of wetlands and to make distinctions between different classes of wetlands. In the case of the Landsat mapping system such fine distinctions are not possible. In addition, when interpreting the CIR photography, adjustments can be made for minor community changes. The Landsat system on the other hand is incapable of making such adjustments once the thresholds have been set from the target sites. Another problem discovered in this study is the lack of a suitable target to background ratio that makes the distinction between upland non-wetland areas from inter-dunal lowland wetland areas more difficult. This problem can be resolved in the future by acquiring photographic and satellite data during June or July rather than in September. In the earlier part of the growing season, the target to background ratio will be greater because of the difference in nonwetland and wetland plant characteristics.

Comparative Delineations of Rice Lake -

Rice ake was delineated by utilizing hydric values for each subtransect in combination with tone and texture characteristics of the 35 mm color infrared imagery. Figures 8 and 9 depict non-hydric and hydric boundaries as well as three wetland zones, submerged aquatic (SA), inner marsh (IM), and outer marsh (OM) for the June and August dates. The submerged aquatic zone was characterized as open water containing floating and submersed aquatic vegetation. Representative species included Lemna minor, L. trisulca, Potamogeton pectinatus and Utricularia vulgaris. The inner marsh zone was dominated by Scirpus acutus, Lemna spp. and Sagittaria. Other species in this zone included Scirpus fluviatilis, Typha latifolia, Sparganium eurycarpum, Polygonum coccineum, P. punctatum, Stachys palustris and some occurrence of hydric grasses and sedges. The outer marsh exhibited the greatest variability in terms of species composition. Hydric grasses and sedges, representative species of the inner marsh zone, and the interspersion of mesic and xeric species typified this area. Appendix C lists the dominant species, hydric values and D_S values for each of the subtransects.

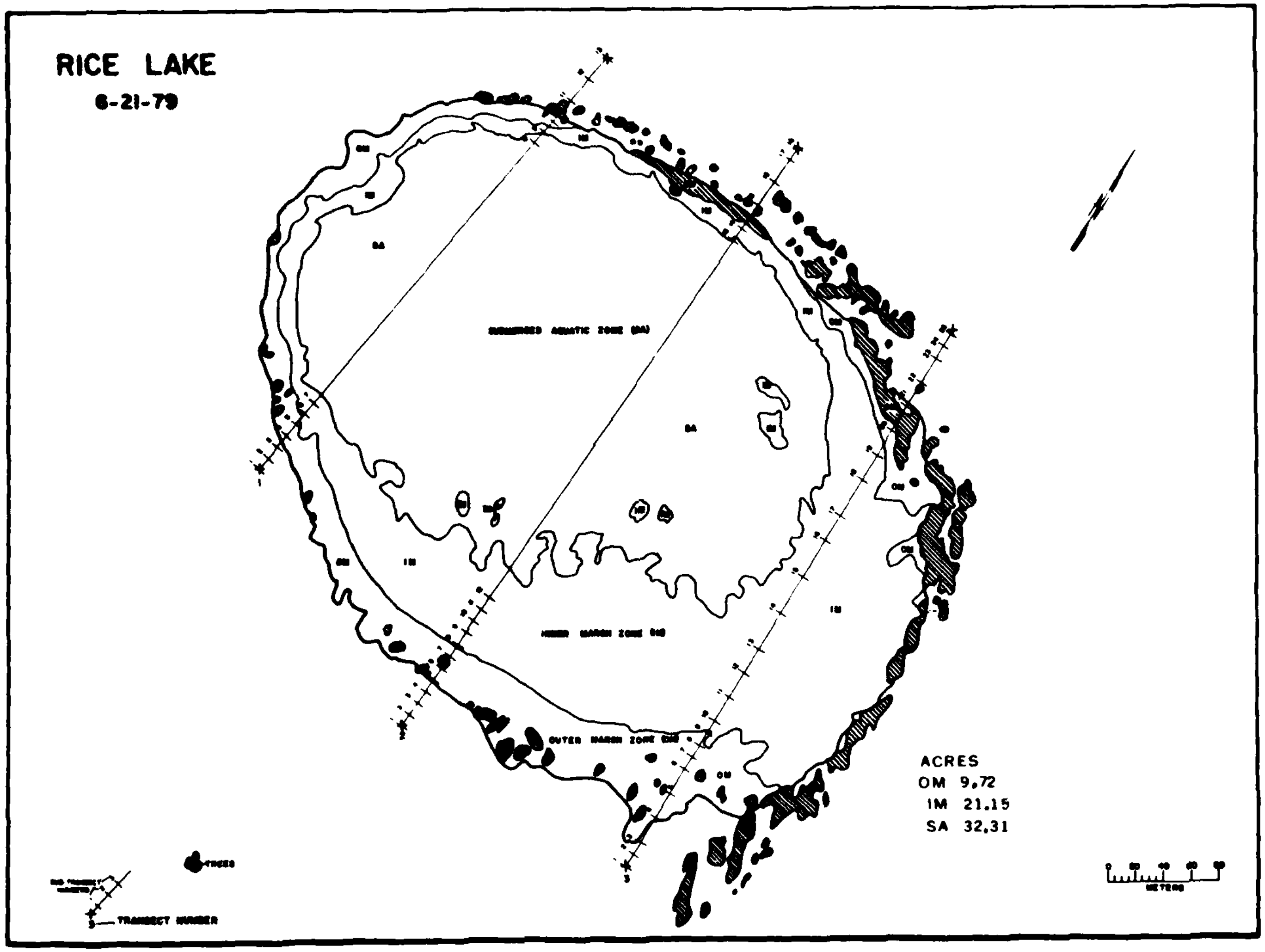


Figure 8. Rice Lake cover map (June).

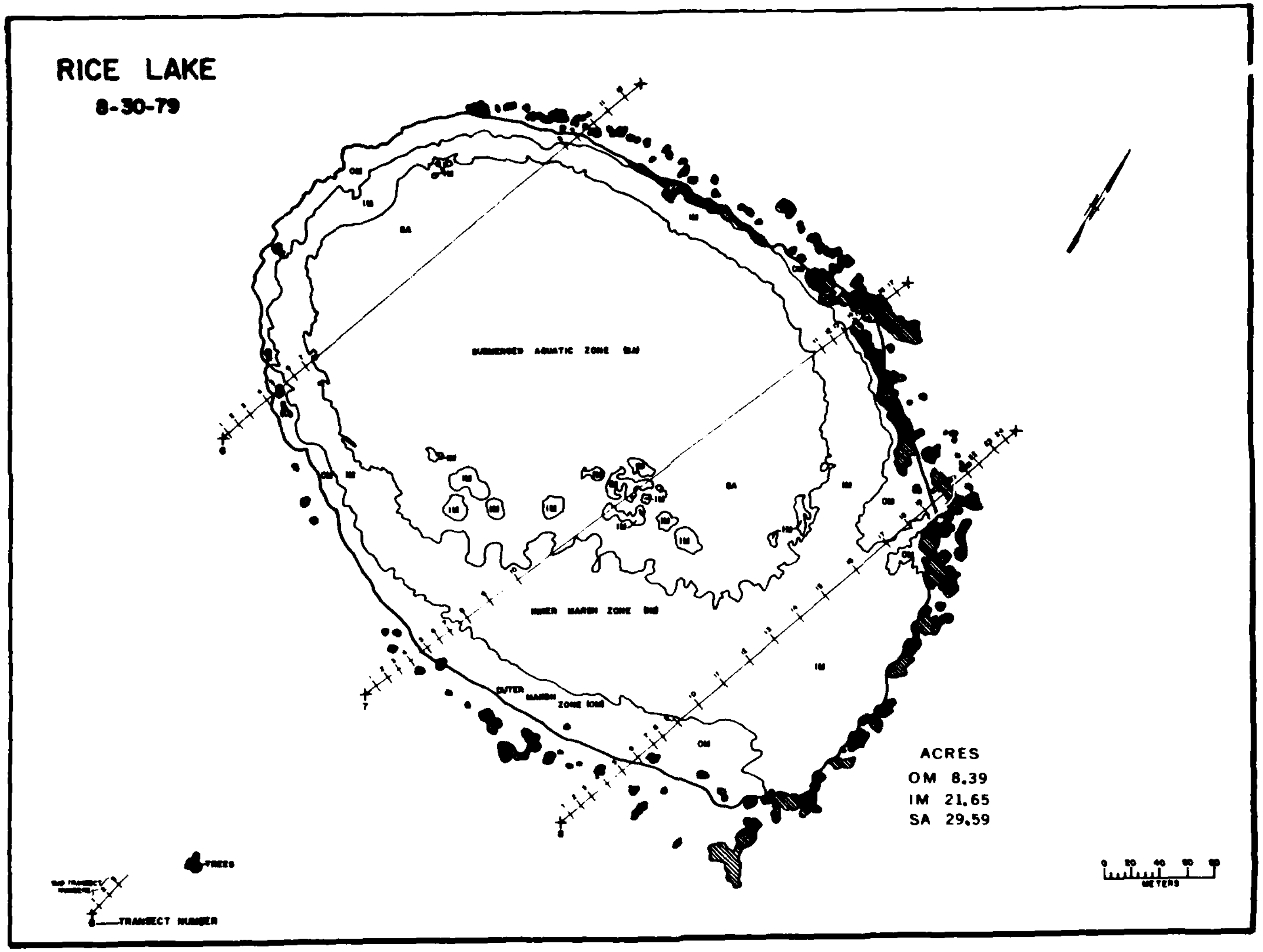


Figure 9. Rice Lake cover map (August).

The August 30 cover map was considered actual for comparisons with the Landsat and 9 x 9 CIR depictions of Rice Lake (Figure 10). Comparisons of these maps should, however, be left to a subjective analysis of general wetland morphology on the part of the reader due to the disparity in classification. The vegetation sampling - 35 mm CIR provided detailed information not available from remote sensing interpretation, necessitating a dissimilar classification to accurately reflect vegetative conditions. Further, the subirrigated meadow class (S), defined by the tonal-textural similarities in the case of 9 x 9 inch CIR and by a range of digital thresholds for Landsat, proved too general for comparisons at this level.

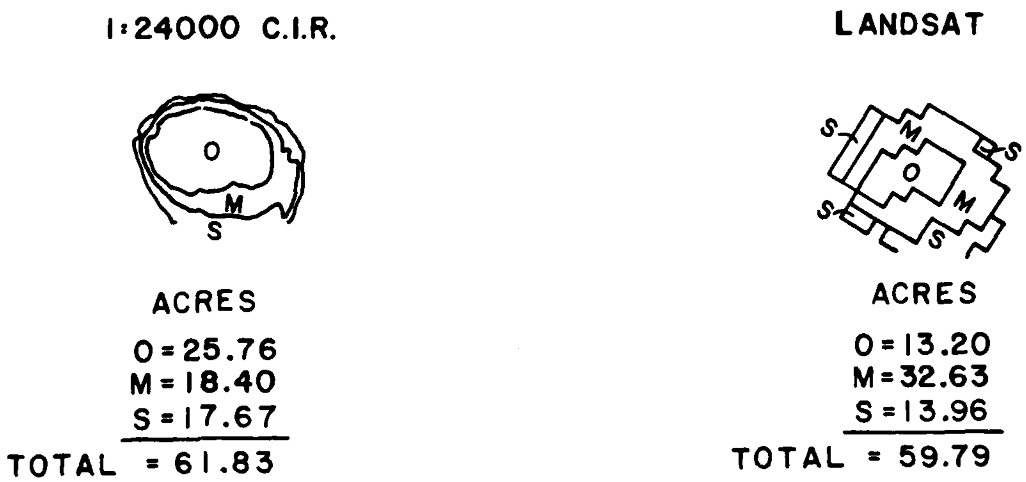


Figure 10. Color infrared-Landsat depictions of Rice Lake.

The gross resolution of a Landsat pixel also limits comparisons to a subjective nature. An individually sensed pixel may have occurred in an area encompassing two or more of the actual vegetation zones.

This pixel would have a reflectance value strongly influenced by the spectral properties of these zones, presenting the possibility for misrepresentation in classification.

Some inferences may be drawn from these comparative depictions. There is no doubt that both manually interpretated CIR and Landsat each represent "prevalence of hydric vegetation" to a certain degree based on the characteristics of the imagery, but actual wetland boundaries can best be determined by incorporating vegetation sampling.

Subirrigated Meadows as Wetlands -

Hydric values for the subirrigated meadows of Transect 5 (Watts Lake) and Transect 4 (Little Hay Valley) are graphically illustrated in Figure 11. This data shows that portions of subirrigated meadows can be classified as wetlands. All subtransects at the two study sites were typified by variable species composition and high species diversity ($D_s(\bar{x})$=.875). Of the 46 subtransects located and sampled in the subirrigated meadow, 18 were considered to occur in wetland areas based on derived hydric values. Hydric values for wetland subtransects ranged from 3.07 to 3.67. Non-hydric subtransects were located near the end points of the main transects in sandhill uplands or atop subtle topographical rises within the more hydric meadow. The wetland subtransects are appropriately described as a hydrophyte grass-sedge zone. Hydric dominants in the subirrigated meadow included _Calamagrostis canadensis_, _C. stricta_, _Spartina pectinata_, _Carex aquatilis_ and _Carex spp._ Other hydric species occurring in association with these dominants were _Eleocharis sp._, _Juncus balticus_, _Equisetum laevigatum_, _Asclepias incarnata_ and _Cicuta maculata_. Ofter interspersed with these species, and in some cases occurring as dominants for wetland subtransects, were _Poa pratensis_ and _Phleum pratense_. These two species, as well as _Calamovilfa longifolia_, _Hordeum jubatum_ and _Panicum virgatum_, also represented transitional species dominants at the hydric/xeric interface. The most xeric subtransects consisted of _Stipa comata_, _Helianthus spp._, _Silphium integrifolium_ and _Lathyrus_ polymorphus. Appendix D lists dominant species, hydric values and D_s values for each subtransect.

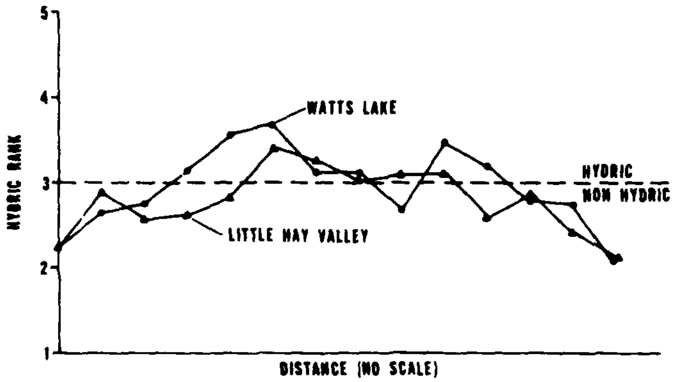


Figure 11. Hydric value profiles for subirrigated meadow study areas (June).

This generalized description of the subirrigated meadow is similar to that described in the literature. Tolstead (1942) defined three vegetative zones in wet meadows: 1) a hydrophytic grass-sedge zone with Calamagrostis spp. and Carex sp. as dominants, 2) a mesophytic tall grass zone consisting of Spartina pectinata, Panicum virgatum, Sorghastrum nutans and Andropogon gerardi, and 3) a true prairie zone dominating the upper portion of the wet meadows and forming a narrow transition between the mesophytic tall grasses and xeric uplands. This distinct zonation and vegetative diversity was also noted by Frolik and Kiem (1933) and Frolik and Shepherd (1940) for wet meadow vegetative types.

Hydric value profiles for Transect 8 (Rice Lake) illustrates a transition from xeric to the extreme of hydric conditions, while transition in Transect 9 (Watts Lake, subirrigated meadow) is apparent, but less pronounced (Figure 12). These differences are attributable to the varying proportions of xeric, mesic, and hydric species occurring along the two transects compared.

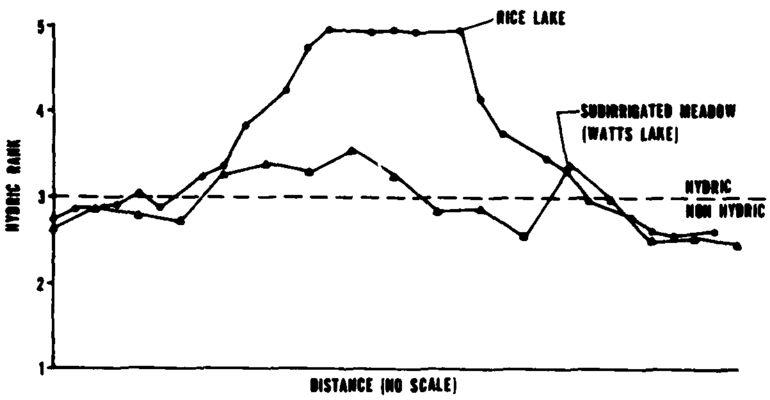


Figure 12. Hydric Value Profile Comparison of Rice Lake - Watts Lake (August).

Differences in the two communities were further defined by evaluation of derived I_m values. Subtransects occurring in similar ecological zones of Rice Lake were compared to grouped non-hydric and hydric subtransects of the subirrigated meadows for both June and August (Table 5).

Subirrigated Meadow / Rice Lake	Non-Hydric I_m	n	Hydric I_m	n
Non-hydric	J - .303	320	J - .119	240
	A - .314	264	A - .047	132
Outer-marsh	J - .098	256	J - .215	192
	A - .075	204	A - .113	102
Inner-marsh	J - .000	320	J - .001	240
	A - .001	168	A - .002	84

Table 5. Morisita's Index ($\bar{x}$) values for community similarity comparisons of Rice Lake vs. subirrigated meadows, for June (J) and August (A).

Greatest community similarity was found in the comparison of non-hydric subtransects. Within hydric subtransects of the subirrigated meadow, highest I_m values were recorded for the outer-marsh comparison at Rice Lake on both dates. This data would indicate that the wet portions of subirrigated meadows most closely resemble the outer-marsh zone in species occurrence and abundance. Community similarity achieved its highest value (.215) in hydric vs. outer-marsh comparisons for June. This may be attributable to the similarity in soil/moisture relationships at the two sites during this part of the growing season. Through summer, however, water levels receded at Rice Lake while ground water levels in the subirrigated meadows may have remained relatively static. This change in available soil moisture in the outer-marsh may account for the decline in the I_m value in the August comparison. Least community similarity was found in the comparison of hydric subirrigated meadow subtransects and the inner-marsh at Rice Lake. Large differences in hydric values of the two areas compared largely account for this non-

correlation. Results summarized in Table 5 did not provide supportive evidence of subirrigated meadows as wetlands, but further substantiated their status as distinct wetland communities.

Temporal Change -

Ground sampling data and imagery for two separate dates (June and August) allowed an analysis of temporal change at Rice Lake. Due to the lack of acceptable imagery from the June sample and haying operations in Little Hay Valley during the August sample, an insufficient data base prevented conducting a similar analysis of subirrigated meadow.

As determined from the base maps, total wetland acres decreased 6% from the June to August sampling dates. As shown in Table 6, the largest drop in acres occurred in the submerged aquatic zone. The decrease in this portion of the wetland is predominantly attributable to the appearance of <u>Lemna</u> <u>spp.</u> and <u>Potamogeton</u> <u>spp.</u> on the water's surface at the submerged aquatic/inner marsh interface. The decrease in the submerged aquatic zone substantially accounts for the .50 acre increase in the inner marsh zone. The data further shows the inner marsh did not increase in the same quantity as the submerged aquatic wetland decreased. This is attributable to the more rapid encroachment of drier outer marsh into the inner marsh as water levels receded through summer.

	June	Aug	Δ Acreage	% Δ
Outer Marsh	9.72	8.39	-1.33	-14%
Inner Marsh	21.15	21.65	+.50	+2%
Submerged Aquatic	32.31	29.57	-2.74	-8%
TOTALS	63.18	59.61	-3.57	-6%

Table 6. Rice Lake acreages and temporal changes.

Hydric values for subtransects sampled in August were similarly lower than those sampled in June, further indicating shrinkage of the marsh inward and the invasion of more xeric species. Hydric value depression in August is graphically represented by a comparison of hydric value profiles of Rice Lake for the two sample dates (see Figure 13).

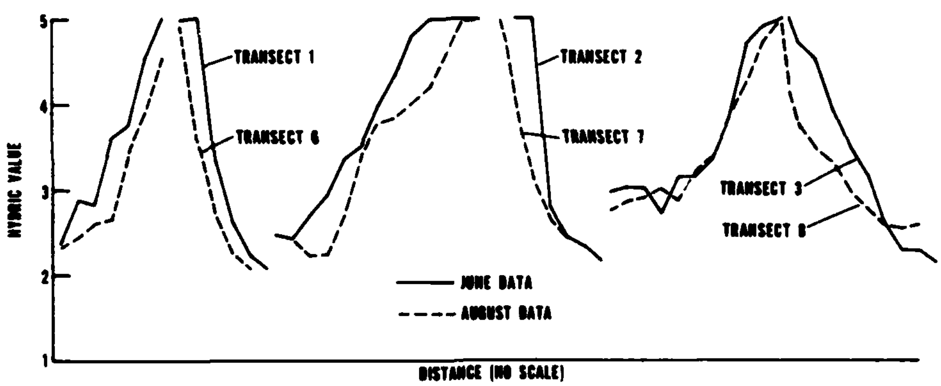


Figure 13. Comparison of hydric value profiles for June and August transects at Rice Lake.

A comparison of D_s values and total number of species for ecologically similar zones on both an intra- and inter-sampling data basis is shown in Table 7. In general, D_s values decreased with an increase in hydric value as indicated by progressively smaller D_s values from non-hydric to inner marsh zones. Additionally, D_s values for all zones decreased from June to August. These trends are illustrated by the graph at Figure 14.

TRANSECT	NON-HYDRIC			OUTER MARSH			INNER MARSH		
	$D_s(\bar{x})$	n	# species	$D_s(\bar{x})$	n	# species	$D_s(\bar{x})$	n	# species
1	.883	6	50	.875	3	40	.732	4	16
2	.877	8	51	.899	3	33	.754	7	16
3	.889	6	39	.841	10	46	.721	9	19
TOTAL (JUN)	.882	20	69	.859	16	67	.735	20	28
6	.865	7	42	.892	3	37	.682	2	11
7	.862	6	46	.858	6	53	.734	5	17
8	.823	9	40	.825	8	50	.655	7	21
TOTAL (AUG)	.847	22	68	.849	17	77	.687	14	28

Table 7. Temporal comparisons of Simpson diversity values and number of species for ecologically similar zones of Rice Lake.

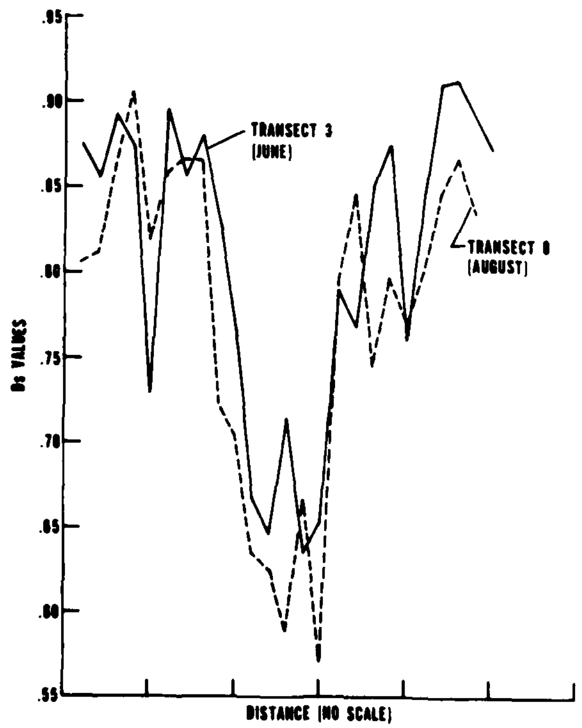


Figure 14. Rice Lake (June-August) D_s values vs. distance.

Though total number of species in non-hydric areas remained static, D_s values lecreased from June to August. This apparent contradiction is attril ted to the dominance of warm season grasses Andropogon hallii and Calamovilfa longifolia in the August sample which depressed IVs of other species. The D_s values for the outer marsh zone similarly decreased over time, but to a lesser degree than non-hydric areas. Totals for the August data indicate D_s values for the outer marsh were slightly higher than values for non-hydric areas. This shift in D_s value hierarchy is partially attributable to an increase from 67 to 77 total species in the outer marsh zone. Inner marsh D_s values were significantly lower than both the non-hydric and outer marsh zones for both dates. A low number of total species and the overall dominance of a Scirpus acutus, Lemna spp. and Sagittaria sp. vegetative triad accounts for the low D_s values.

I_m values were also compared for ecologically similar zones between the two sample dates as shown in Table 8. This data indicates the largest community change occurs in the outer marsh zone and is highly correlated to this area's receding water levels and fluctuating soil/ moisture relationships. The least community change occurs in the inner

	NON-HYDRIC		OUTER MARSH		INNER MARSH	
	$I_m(\bar{x})$	n	$I_m(\bar{x})$	n	$I_m(\bar{x})$	n
TRANSECT 1 vs 6	.319	42	.196	9	.584	8
TRANSECT 2 vs 7	.372	48	.205	18	.605	35
TRANSECT 3 vs 8	.198	54	.205	80	.784	63
TOTALS	.297	144	.204	107	.710	106

Table 8. Temporal comparison of Rice Lake using Morisita's Index $(\bar{x})$ values.

marsh where standing water is present throughout the year and the environment is comparatively stable. The dominant *Scirpus-Lemna-Sagittaria* association remains relatively unchanged in this zone during the entire growing season.

The relative amount of species disappearance and replacement was analyzed by comparing ecologically similar zones at Rice Lake through the Sorenson Community Coefficient (CC_s). This data is summarized in Table 9. CC_s values further indicate the large community change and species turn-over which occurs in the outer marsh zone. The low CC_s value for the inner marsh zone indicates that substantial shifts take place in vegetative sub-dominants though such changes are masked by the stability and dominance of the *Scirpus-Lemna-Sagittaria* association.

	# species June	# species August	Δ species	CC_s
Non-hydric	69	68	59	.569
Outer marsh	67	77	74	.486
Inner marsh	28	28	36	.357

Table 9. Species disappearance/replacement data and Sorenson Community Coefficient values for Rice Lake.

- CONCLUSIONS -

This study documented the accuracy of Landsat wetland mapping in the Sandhills of Nebraska. Methodology for delineation of wetland communities and the determination of subirrigated meadows as wetlands has been established. Comparisons of the various remote sensor's depictions of Rice Lake proved inconclusive due to the incompatible classifications and resolutions. Significant vegetation changes have been noted in the temporal evaluation of Rice Lake. Additional studies are essential to place in proper perspective the remote sensing and field results. These studies may include:

1. Incorporating the various remote sensors and field evaluation techniques into an operational framework for the Corps regulatory responsibilities.

2. Testing of field evaluation methods in other types of wetland environments, (i.e.) Missouri River floodplain wetlands.

3. Refinement in separation of hydric subirrigated meadows by Landsat through computer manipulation of digital data or temporal analysis.

4. Additional vegetational studies of subirrigated meadows with respect to variations in topography, ground water, soils information and comparisons of grazed, mowed, and undisturbed areas.

5. Additional transition zone studies.

6. The effects of temporal changes on wetland delineation.

7. Determining least number of sample plots required to achieve acceptable wetland delineation.

- ACKNOWLEDGMENTS -

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- LITERATURE CITED -

Bragg, T. B. 1978. Effects of burning, cattle grazing, and topography on vegetation of the Choppy Sands range site in the Nebraska Sandhills Prairie. Pages 248-253 in D. N. Hyder, editor, Proceedings of the First International Rangeland Congress, Denver, Colorado. 14-18 August 1978.

Brinegar, T. E. and F. D. Keim. 1942. The relations of vegetative composition and cattle grazing on Nebraska range land. University of Nebraska Agricultural Experiment Station Research Bulletin 123.

Bussom, D. E. and D. C. Rundquist. 1978. An example of one user algorithm for analysis of unrectified Landsat digital imagery. Remote Sensing of the Electro-Magnetic Spectrum, 5(a):29-39.

Carter, V., D. L. Malone, and J. H. Burbank. 1979. Wetland classification and mapping in western Tennessee. Photogrammetric Engineering and Remote Sensing, 45(3):273-284.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deep-water habitats of the United States. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C., 100pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33(1):43-64.

Frolik, A. L. and F. D. Keim. 1933. Native vegetation in the prairie hay district of north central Nebraska. Ecology 14:298-305.

Frolik, A. L. and W. O. Shepherd. 1940. Vegetation composition and grazing capacity of a typical area of Nebraska sandhill range land. University of Nebraska Agricultural Experiment Station Bulletin 117.

Gilmer, D. S., J. E. Colwell and E. A. Work. 1978. Use of Landsat for evaluation of waterfowl habitat in the prairie pothole region. Pages 197-203 in Proceeding of the Pecora IV Symposium, Application of Remote Sensing Data to Wildlife Management, Sioux Falls, South Dakota. 10-12 October 1978.

LaPerriere, A. J. and J. W. Morrow. 1978. Use of Landsat data for the wetland inventory of Alaska. Pages 95-99 in Proceedings of the Pecora IV Symposium, Application of Remote Sensing Data to Wildlife Management, Sioux Falls, South Dakota. 10-12 October 1978.

McMurtrey, M. D., R. Craig and G. Schildman. 1972. Survey of habitat, Nebraska wetlands survey. Nebraska Game and Parks Commission.

Meyer, M. and P. Grumstrup. 1978. Operating manual for the Montana 35 mm aerial photography system - 2nd revision. University of Minnesota IAFHE Research Report 78-1, 62pp.

Montanari, J. H. and B. O. Wilen. 1978. Techniques developed and presently being used to conduct the National Wetland Inventory Project. Pages 205-212 in Proceedings of the National Wetland Protection Symposium, Reston, Virginia. 6-8 June 1977.

Nyc, R. and P. Brooks. 1979. National Wetlands Inventory Project, inventorying the nation's wetlands with remote sensing. Pages 333-343 in Proceedings of the U.S. Army Corps of Engineers Remote Sensing Symposium, Reston, Virginia. 29-31 October 1979.

Owens, T. and M. Meyer. 1978. A wetlands survey of the Twin Cities 7-county metropolitan area-east half. University of Minnesota IAFHE Research Report 78-2, 19pp.

Pool, R. J. 1914. A study of the vegetation of the Sandhills of Nebraska. Minnesota Botanical Studies 4:189-312.

Rundquist, D. C. and J. S. Linden. 1979. Toward a digital classification of wetlands in the Nebraska Sandhills region: a test of Landsat MSS data. Final report, research sponsored by the Charles A. Lindbergh Fund, Inc., New York City, 85pp.

Rundquist, D. C. and J. K. Turner. 1980. Wetlands inventory of the Omaha District. Interim report, research sponsored by the Omaha District, U.S. Army Corps of Engineers, Omaha, Nebraska, 33pp.

Rydberg, P. A. 1895. Flora of the Sandhills of Nebraska. Contributions United States National Herbarium, Volume III. Pages 133-148.

Sather, J. H. 1958. Biology of the Great Plains muskrat in Nebraska. Wildlife Monograph No. 2, May 1958.

Seevers, P., R. Peterson, D. Mahoney, D. Maroney, and D. Rundquist. 1974. An inventory of Nebraska wetlands with the use of imagery from the Earth Resources Technology Satellite. Pages 281-292 in Proceedings of the Fourth Annual Remote Sensing of Earth Resources Conference, University of Tennessee Space Institute, March, 1975.

Shaw, S. P. and C. G. Fredine. 1956. Wetlands of the United States. U.S. Fish and Wildlife Service Circular 39. 67pp.

Smith, J. G. 1892. The grasses of the Sandhills of northern Nebraska. Nebraska State Board of Agriculture, Report of the Botanist: 1892. Lincoln, Nebraska. Pages 280-291.

Tolstead, W. L. 1942. Vegetation of the northern part of Cherry County, Nebraska. Ecological Monographs 12(3):255-292.

Werth, L. F. and M. Meyer. 1979. A comparison of remote sensing techniques for Minnesota wetlands classification. Proceedings of the Fifth Annual William T. Pecora Symposium on Satellite Hydrology, Sioux Falls, South Dakota. 10-15 June 1979.

Work, E. A. and D. S. Gilmer. 1976. Utilization of satellite data for inventorying prairie ponds and lakes. Photogrammetric Engineering and Remote Sensing 42(5)685-694.

WETLAND STUDY	WETLAND STUDY AREA DATE TIME	COVERAGE CATEGORIES 2 = <5% 1 15 = 5-25% 2 38 = 25-50% 3 62 = 50-75% 4 85 = 75-95% 5 98 = >95% 6	TRANSECT SUBTRANSECT AZIMUTH

PLOT DATA

PLOT NO.	STANDING VEGETATION: TOTAL COVER	STANDING VEGETATION: % GREEN	STANDING VEGETATION: % NON GREEN	PERCENT COVER: BARE SOIL % COVER	PERCENT COVER: OPEN WATER % COVER	ALLOCATION OF VEGETATION COVER %: GRASS SEDGE	FORBS	WOODY PLANTS	AQUATIC EMERGENT	AQUATIC FLOATING	OTHER
1											
2											
3											
4											
5											
6											
7											
8											
9											
0											

GENERIC NAME	SPECIES NAME	ID NO	SPECIES COVERAGE AT EACH PLOT: 1	2	3	4	5	6	7	8	9	0

Appendix A. Sample data sheet (original is 8½ x 14).

Appendix B. Listing of Plants Collected for Rice Lake and the Subirrigated Meadow Study Sites. Hydric Rank in ( ).

Achillea millefolium (3)

Agalinus gattingeri (4)

Agrimonia gryposepala (3)

Agrimonia striata (3)

Agropyron smithii (3)

Agrostis stolonifera (4)

Alisma sp. (5)

Ambrosia psilostachya (2)

Amorpha canescens (2)

Andropogon hallii (2)

Andropogon scoparius (2)

Antennaria neglecta (2)

Apocynum sibiricum (3)

Artemesia ludoviciana (2)

Asclepias incarnata (4)

Asclepias sp. (3)

Aster ericoides (2)

Aster praealtus (4)

Aster sp. (3)

Bidens cernua (4)

Bidens coronata (4)

Bouteloua gracilis (2)

Bromus inermis (3)

Bromus japonicus (3)

Brycphyte (3)

Calamagrostis canadensis (4)

Calamagrostis stricta (4)

Calamovilfa longifolia (2)

Campanula aparinoides (4)

Carex aquatilis (4)

Carex 1 (3)

Carex 2 (3)

Carex 3 (4)

Carex 4 (4)

Carex 5 (4)

Carex 6 (2)

Carex 7 (2)

Carex 8 (3)

Carex 9 (3)

Carex 10 (3)

Cerastium nutans (3)

Chenopodium album (3)

Chenopodium sp. (3)

Cicuta maculata (4)

Cirsium plattense (2)

Cirsium sp. (3)

Collomia linearis (2)

Compositae (3)

Convolvulus arvensis (3)

Conyza canadensis (2)

Cristatella jamesii (1)

Cyperus schweinitzii (3)

Cyperus sp.1 (3)
Cyperus sp.? (4)
Descurainia sophia (2)
Eleocharis sp. (4)
Elymus canadensis (3)
Epilobium adenocaulon (4)
Eragrostis spectabilis (2)
Eragrostis trichodes (2)
Erigeron strigosus (3)
Equisetum arvense (4)
Equisetum laevigatum (4)
Euphorbia missurica (2)
Euphorbia sp. (3)
Festuca octoflora (2)
Forb UK (3)
Fungi (3)
Galium sp. (4)
Geum aleppicum (4)
Glycyrrhiza lepidota (3)
Glyceria striata (4)
Haplopappus spinulosus (2)
Helianthus annuus (3)
Helianthus petiolaris (2)
Helianthus rigidus (2)
Helianthus tuberosus (3)
Helianthus sp. (3)
Hordeum jubatum (2)
Hypericum majus (4)
Hypoxis hirsuta (3)
Iva xanthifolia (3)
Juncus balticus (4)
Juncus interior (4)
Juniperus virginiana (2)
Kochia scoparia (3)
Koeleria pyrimidata (2)
Kuhnia eupatorioides (2)
Labiatae 1 (3)
Labiatae 2 (3)
Lactuca sp. (3)
Lappula redowskii (2)
Lathyrus polymorphus (2)
Leersia oryzoides (4)
Lemna minor (5)
Lemna trisulca (5)
Lepidium virginicum (2)
Lespedeza capitata (2)
Lesquerella ludoviciana (2)
Liatris lancifolia (3)
Liatris squarrosa (2)
Lithospermum incisum (2)
Lithospermum sp. (3)
Lobelia siphilitica (4)
Lycopus sp. (4)
Lygodesmia juncea (2)
Malva sp. (3)
Medicago lupulina (3)

Mentzelia nuda (2)

Mentzelia stricta (2)

Muhlenbergia pungens (1)

Muhlenbergia racemosa (3)

Mysotis sylvatica (3)

Oenothera pallida (2)

Oenothera strigosa (3)

Onoclea sensibilis (4)

Opuntia compressa (1)

Oxalis stricta (3)

Panicum capillare (3)

Panicum lanuginosum (3)

Panicum oligosanthes (3)

Panicum virgatum (3)

Paspalum stramineum (2)

Penstemon gracilis (2)

Petalostemum villossum (1)

Phalaris arundinacea (4)

Phleum pratense (3)

Physalis virginiana (3)

Physalis sp. (3)

Plantago patagonica (1)

Poa compressa (2)

Poa palustris (4)

Poa pratensis (3)

Polygonum coccineum (4)

Polygonum convolvulus (3)

Polygonum punctatum (4)

Polygonum ramosissimum (3)

Polygonum sagittatum (4)

Populus deltoides (4)

Potamogeton natans (5)

Potamogeton pectinatus (5)

Potamogeton sp. (5)

Potentilla norvegica (4)

Prunus besseyi (2)

Psoralea argophylla (2)

Psoralea digitata (2)

Ratibida columnifera (2)

Redfieldia flexuosa (1)

Rhus radicans (3)

Rosa arkansana (2)

Rudbeckia hirta (3)

Rumex sp. (3)

Sagittaria sp. (5)

Salix amygdaloides (4)

Salix exigua (4)

Salix sp. (4)

Scirpus acutus (5)

Scirpus americanus (5)

Scirpus fluviatilis (5)

Scuttellaria parvula (4)

Senecio ridellii (2)

Silene antirrhina (2)

Silphium integrifolium (3)

Solidago candensis (3)

Solidago graminifolia (3)
Solidago rigida (2)
Solidago sp.1 (3)
Solidago sp.2 (3)
Sonchus uliginosus (3)
Sorghastrum nutans (2)
Sparganium eurycarpum (5)
Spartina pectinata (4)
Stachys palustris (4)
Stellaria longifolia (4)
Stipa comata (2)
Strophostyles leiosperma (3)
Symphoricarpos sp. (3)
Sisyrinchium angustifolium (3)
Taraxacum officinale (3)
Thelesperma sp. (3)
Thelypteris palustris (4)
Thlaspi arvense (3)
Tradescantia occidentalis (3)
Tragopogon pratensis (3)
Trifolium pratense (3)
Trifolium repens (3)
Typha latifolia (5)
Urtica sp. (3)
Utricularia vulgaris (5)
Verbena stricta (2)
Verbena urticifolia (3)
Viola pedatifida (2)
Yucca glauca (1)

Appendix C. Subtransect Data for Rice Lake, June and August. D_s=Simpson Diversity Index and HV=Hydric Value. Dominant Species Listed Were Those With the Highest IV's Where the Sum was Greater Than or Equal to 50% of all IV's Occurring in the Subtransect.

I. June

Transect 1:

Subtransect

1-01: D_s=.92, HV=2.38

Eragrostis trichodes
Lathyrus polymorphus
Stellaria longifolia
Koeleria pyrimidata

1-02: D_s=.90, HV=2.88

Solidago sp. 1
Panicum virgatum
Juncus balticus
Aster ericoides

1-03: D_s=.79, HV=2.85

Solidago sp. 1
Andropogon hallii

1-04: D_s=.84, HV=3.60

Salix exigua
Solidago sp. 2
Carex 5

1-05: D_s=.90, HV=3.77

Scirpus acutus
Solidago sp. 2
Geum aleppicum
Carex 4

1-06: D_s=.83, HV=4.56

Typha latifolia
Scirpus acutus
Sagittaria sp.

1-07: D_s=.76, HV=4.99

Sparganium eurycarpum
Lemna minor

1-08: D_s=.61, HV=4.98

Sagittaria sp.

1-09: D_s=.72, HV=4.99

Sagittaria sp.
Lemna minor

1-10: D_s=.89, HV=3.36

Carex 8
Carex 3
Carex 1

1-11: D_s=.90, HV=2.62

Panicum virgatum
Panicum oligosanthes
Helianthus tuberosus
Artemesia ludoviciana

1-12: D_s=.89, HV=2.25

Andropogon scoparius
Andropogon hallii
Stipa comata
Helianthus tuberosus

1-13: D_s=.90, HV=2.08

Stipa comata
Lathyrus polymorphus
Andropogon scoparius
Eragrostis trichodes
Calamovilfa longifolia

Transect 2:

Subtransect

2-01: D_s=.90, HV=2.48

Solidago rigida
Calamovilfa longifolia
Artemesia ludoviciana
Juncus balticus

2-02: D_s=.80, HV=2.43

Calamovilfa longifolia
Juncus balticus
Solidago rigida

2-03: D_s=.86, HV=2.71

Calamovilfa longifolia
Juncus balticus
Artemesia ludoviciana

2-04: D_s=.90, HV=2.95

Juncus balticus
Calamovilfa longifolia
Artemesia ludoviciana
Poa pratensis

2-05: D_s=.89, HV=3.37

Juncus balticus
Stachys palustris
Salix exigua
Phleum pratense

2-06: D_s=.88, HV=3.51

Juncus balticus
Carex 10
Solidago sp. 1
Salix exigua

2-07: D_s=.92, HV=3.99

Scirpus acutus
Polygonum coccineum
Carex 1
Carex 5
Verbena urticifolia
Salix exigua

2-08: D_s=.83, HV=4.35

Scirpus acutus
Polygonum coccineum

2-09: D_s=.75, HV=4.79

Scirpus acutus
Sparganium eurycarpum

2-10: D_s=.77, HV=4.98

Scirpus acutus
Sagittaria sp.

2-11: D_s=.71, HV=4.99

Scirpus acutus
Sagittaria sp.

2-12: D_s=.76, HV=4.99

Scirpus fluviatilis
Scirpus acutus

2-13: D_s=.71, HV=4.99

Sagittaria sp.
Sparganium eurycarpum

2-14: D_s=.75, HV=4.99

Sagittaria sp.
Scirpus fluviatilis

2-15: D_s=.90, HV=2.81

Calamovilfa longifolia
Salix exigua
Solidago sp. 1
Artemesia ludoviciana

2-16: D_s=.86, HV=2.47

Stipa comata
Equisetum laevigatum
Panicum virgatum

2-17: D_s=.88, HV=2.36

Stipa comata
Helianthus tuberosus
Panicum virgatum
Andropogon scoparius

2-18: D_s=.87, HV=2.18

Eragrostis trichodes
Rosa arkansana
Stipa comata
Helianthus tuberosus

Transect 3:

Subtransect

3-01: D_s=.87, HV=2.98

Carex 8
Juncus balticus
Panicum virgatum

3-02: D_s=.85, HV=3.02

Phleum pratense
Carex 10
Poa pratensis

3-03: D_s=.89, HV=3.01

Carex 8
Carex 10
Stachys palustris
Poa pratensis

3-04: D_s=.87, HV=2.73

Artemesia ludoviciana
Carex 8
Juncus balticus
Hordeum jubatum

3-05: D_s=.73, HV=3.15

Carex 8
Juncus balticus

3-06: D_s= .89, HV=3.17

Carex 8
Juncus balticus
Carex 10
Verbena stricta

3-07: D_s=.86, HV=3.34

Carex 10
Carex 8
Scirpus acutus

3-08: D_s=.88, HV=3.80

Carex 1
Polygonum coccineum
Scirpus acutus

3-09: D_s=.83, HV=4.69

Scirpus acutus
Sparganium eurycarpum
Typha latifolia

3-10: D_s=.76, HV=4.91

Scirpus acutus
Sparganium eurycarpum

3-11: D_s=.67, HV=4.99

Scirpus acutus

3-12: D_s=.65, HV=5.00

Scirpus acutus

3-13: D_s=.71, HV=4.95

Scirpus acutus
Lemna minor

3-14: D_s=.63, HV= 5.00

Lemna minor
Scirpus acutus

3-15: D_s=.65, HV=5.00

Scirpus acutus
Lemna minor

3-16: D_s=.79, HV=4.92

Scirpus acutus
Lemna minor

3-17: D_s=.77, HV=4.71

Scirpus acutus
Sagittaria sp.

3-18: D_s=.85, HV=4.53

Scirpus acutus
Scirpus fluviatilis
Sparganium eurycarpum

3-19: D_s=.87, HV=3.93

Scirpus acutus
Verbena urticifolia
Polygonum coccineum

3-20: D_s=.76, HV=3.49

Salix amygdaloides
Carex 8

3-21: D_s=.85, HV=3.18

Juncus balticus
Poa pratensis
Solidago sp. 1

3-22: D_s=.91, HV=2.62

Artemesia ludoviciana
Helianthus tuberosus
Polygonum coccineum
Panicum virgatum
Eragrostis trichodes

3-23: D_s=.91, HV=2.30

Andropogon hallii
Lathyrus polymorphus
Helianthus tuberosus
Stipa comata
Andropogon scoparius

3-24: D_s=.89, HV=2.29

Lathyrus polymorphus
Stipa comata
Andropogon hallii
Helianthus tuberosus

3-25: D_s=.87, HV=2.17

Andropogon hallii
Stipa comata
Rosa arkansana

II. August

Transect 6:

Subtransect

6-01: D_s=.87, HV=2.33

Panicum virgatum
Andropogon scoparius
Rhus radicans

6-02: D_s=.83, HV=2.45

Rhus radicans
Prunus besseyi
Panicum virgatum

6-03: D_s=.82, HV=2.61

Panicum virgatum
Artemesia ludoviciana
Rhus radicans

6-04: D_s=.86, HV=2.67

Solidago canadensis
Andropogon hallii
Calamovilfa longifolia

6-05: D_s=.89, HV=3.44

Carex 10
Solidago candensis
Aster praealtus

6-06: D_s=.89, HV=3.92

Scirpus acutus
Polygonum punctatum
Carex 5

6-07: D_s=.84, HV=4.56

Carex 5
Sagittaria sp.
Lemna minor

6-08: D_s=.53, HV=4.90

Sagittaria sp.

6-09: D_s=.90, HV=3.58

Muhlenbergia racemosa
Phalaris arundinacea
Solidago canadensis

6-1 · D_s=.88, HV=2.73

Panicum virgatum
Helianthus annuus
Artemesia ludoviciana
Rosa arkansana

6-11: D_s=.90, HV=2.27

Andropogon hallii
Helianthus annuus
Andropogon scoparius
Helianthus rigidus

6-12: D_s=.87, HV=2.10

Andropogan scoparius
Andropogon hallii
Rosa arkansana

Transect 7:

Subtransect

7-01: D_s=.83, HV=2.42

Andropogon hallii
Artemesia ludoviciana
Panicum virgatum

7-02: D_s=.84, HV=2.23

Andropogon hallii
Calamovilfa longifolia

7-03: D_s=.83, HV=2.25

Calamovilfa longifolia
Andropogon hallii

7-04: D_s=.89, HV=2.68

Calamovilfa longifolia
Solidago canadensis
Salix sp.
Panicum virgatum

7-05: D_s=.88, HV=3.41

Salix exigua
Solidago canadensis
Muhlenbergia racemosa

7-06: D_s=.87, HV=3.78

Salix exigua
Spartina pectinata
Stachys palustris

7-07: D_s=.89, HV=3.84

Polygonum punctatum
Scirpus acutus
Geum aleppicum
Lespedeza capitata

7-08: D_s=.81, HV=4.19

Stachys palustris
Polygonum punctatum
Scirpus acutus

7-09: D_s=.69, HV=4.99

Scirpus acutus
Sagittaria sp.

7-10: D_s=.73, HV=5.00

Sagittaria sp.
Lemna minor

7-11: D_s=.66, HV=5.00

Sagittaria sp.
Lemna minor

7-12: D_s=.78, HV=4.71

Sagittaria sp.
Sparganium eurycarpum

7-13: D_s=.87, HV=4.10

Scirpus acutus
Salix sp.
Spartina pectinata

7-14: D_s=.79, HV=3.56

Spartina pectinata
Solidago canadensis

7-15: D_s=.86, HV=3.15

Populus deltoides
Panicum virgatum
Solidago canadensis
Calamovilfa longifolia

7-16: D_s=.91, HV=2.68

Helianthus annuus
Calamovilfa longifolia
Populus deltoides
Andropogon hallii

7-17: D_s=.87, HV=2.44

Helianthus annuus
Panicum virgatum
Calamovilfa longifolia

Transect 8:

<u>Subtransect</u>

8-01: D_s=.80, HV=2.76

Carex 10
Aster ericoides

8-02: D_s=.81, HV=2.87

Carex 10
Aster ericoides

8-03: D_s=.86, HV=2.90

Panicum virgatum
Carex 10
Ambrosia psilostachya

8-04: D_s=.90, HV=3.01

Carex 10
Artemesia ludoviciana
Spartina pectinata
Ambrosia psilostachya

8-05: D_s=.82, HV=2.88

Carex 10
Artemesia ludoviciana
Solidago canadensis

8-06: D_s=.86, HV=3.22

Carex 10
Apocynum sibiricum
Juncus balticus

8-07: D_s=.87, HV=3.35

Carex 10
Apocynum sibiricum
Muhlenbergia racemosa

8-08: D_s=.86, HV=3.83

Polygonum punctatum
Carex 10
Scirpus acutus

8-09: D_s=.72, HV=4.26

Polygonum punctatum
Scirpus acutus

8-10: D_s=.70, HV=4.73

Scirpus acutus
Sagittaria sp.

8-11: D_s=.63, HV=4.98

Scirpus acutus

8-12: D_s=.63, HV=4.94

Scirpus acutus

8-13: D_s=.59, HV=4.96

Scirpus acutus

8-14: D_s=.67, HV=4.92

Scirpus acutus

8-15: D_s=.57, HV=4.95

Typha latifolia
Scirpus acutus

8-16: D_s=.80, HV=4.15

Scirpus acutus
Polygonum punctatum

8-17: D_s=.85, HV=3.77

Polygonum punctatum
Scirpus acutus
Verbena urticifolia

8-1 : D_s=.75, HV=3.48

Poa pratensis
Scirpus acutus

8-19: D_s=.80, HV=3.32

Poa pratensis
Stachys palustris
Salix exigua

8-20: D_s=.77, HV=2.98

Poa pratensis
Panicum virgatum

8-21: D_s=.80, HV=2.79

Panicum virgatum
Panicum oligosanthes

8-22: D_s=.84, HV=2.59

Panicum virgatum
Calamovilfa longifolia
Artemesia ludoviciana

8-23: D_s= .87, HV=2.56

Panicum virgatum
Helianthus annuus
Calamovilfa longifolia

8-24: D_s=.83, HV=2.60

Helianthus annuus
Panicum virgatum
Calamovilfa longifolia

Appendix D. Subtransect Data for Subirrigated Meadows. D_s=Simpson Diversity Index and HV=Hydric Value. Dominant Species Listed Were Those with the Highest IV's Where the Sum was Greater Than 50% of all IV's Occurring in the Subtransect.

I. Little Hay Valley (June)

Transect 4:

Subtransect

4-01: D_s=.90, HV=2.27

Stipa comata
Eragrostis trichodes
Lathyrus polymorphus
Helianthus tuberosus

4-02: D_s=.85, HV=2.91

Poa pratensis
Carex 8
Iva xanthifolia

4-03: D_s=.86, HV=2.58

Poa pratensis
Stipa comata
Agropyron smithii

4-04: D_s=.89, HV=2.60

Poa pratensis
Panicum virgatum
Stipa comata
Aster ericoides

4-05: D_s=.90, HV=2.86

Achillea millefolium
Poa pratensis
Agropyron smithii
Stipa comata

4-06: D_s=.83, HV=3.41

Carex 8
Carex 3

4-07: D_s=.90, HV=3.26

Carex 8
Phleum pratense
Carex 1
Carex 9

4-08: D_s=.89, HV=3.07

Phleum pratense
Trifolium pratense
Poa pratensis
Eleocharis sp.

4-09: D_s=.85, HV=3.15

Carex 8
Phleum pratense

4-10: D_s=.92, HV=3.13

Agrostis stolonifera
Calamovilfa longifolia
Achillea millefolium
Panicum oligosanthes
Equisetum laevigatum

4-11: D_s=.85, HV=2.61

Panicum virgatum
Lathyrus polymorphus
Artemesia ludoviciana

4-12: D_s=.90, HV=2.83

Panicum virgatum
Andropogon scoparius
Helianthus tuberosus
Artemesia ludoviciana

4-13: D_s=.89, HV=2.42

Panicum virgatum
Ambrosia psilostachya
Artemesia ludoviciana
Psoralea argophylla

4-14: D_s=.89, HV=2.14

Stipa comata
Eragrostis trichodes
Koeleria pyrimidata
Lathyrus polymorphus

II. Watts Lake (June)

Transect 5:

Subtransect

5-01: D_s=.88, HV=2.34

Stipa comata
Panicum virgatum
Koeleria pyrimidata

5-02: D_s=.89, HV=2.66

Poa pratensis
Stipa comata
Bromus inermis

5-03: D_s=.89, HV=2.79

Poa pratensis
Bromus inermis
Lathyrus polymorphus

5-04: D_s=.87, HV=3.12

Poa pratensis
Trifolium pratense
Phleum pratense

5-05: D_s=.87, HV=3.57

Calamagrostis canadensis
Carex 3
Poa pratensis

5-06: D_s=.88, HV=3.67

Carex aquatilis
Carex 3
Calamagrostis canadensis

5-07: D_s=.84, HV=3.12

Poa pratensis
Trifolium pratense
Phleum pratense

5-08: D_s=.87, HV=3.15

Poa pratensis
Trifolium pratense
Phleum pratense

5-09: D_s=.91, HV=2.69

Panicum virgatum
Artemesia ludoviciana
Carex 2
Poa pratensis

5-10: D_s=.90, HV=3.50

Carex aquatilis
Poa pratensis
Carex 3
Eleacharis sp.

5-11: D_s=.93, HV=3.21

Poa pratensis
Juncus balticus
Carex 3
Phleum pratense
Helianthus tuberosus

5-12: D_s=.90, HV=2.80

Panicum virgatum
Calamovilfa longifolia
Juncus balticus
Equisetum laevigatum

5-13: D_s=.89, HV=2.74

Panicum virgatum
Equisetum laevigatum
Artemesia ludoviciana
Solidago rigida

5-14: D_s=.91, HV=2.15

Stipa comata
Lathyrus polymorphus
Koeleria pyrimidata
Artemesia ludoviciana
Calamovilfa longifolia

III. Watts Lake (August)

Transect 9:

Subtransect

9-01: D_s=.89, HV=2.68

Silphium integrifolium
Poa compressa
Phleum pratense
Calamovilfa longifolia

9-02: D_s=.93, HV=2.88

Panicum virgatum
Silphium integrifolium
Bromus inermis
Agrostis stolonifera
Ambrosia psilostachya

9-03: D_s=.91, HV=2.81

Silphium integrifolium
Poa compressa
Chenopodium album
Bromus inermis
Panicum virgatum
Artemesia ludoviciana

9-04: D_s=.89, HV=2.74

Andropogon hallii
Elymus canadensis
Phleum pratense
Spartina pectinata

9-05: D_s=.80, HV=3.29

Spartina pectinata
Silphium integrifolium

9-06: D_s=.86, HV=3.41

Spartina pectinata
Calamagrostis stricta
Carex aquatilis

9-07: D_s=.79, HV=3.30

Calamagrostis stricta
Carex 10
Poa compressa

9-08: D_s=.84, HV=3.57

Calamagrostis stricta
Spartina pectinata

9-09: D_s=.87, HV=3.25

Calamagrostis stricta
Spartina pectinata
Poa compressa

9-10: D_s=.87, HV=2.82

Spartina pectinata
Calamovilfa longifolia
Andropogon hallii

9-11: D_s=.88, HV=2.87

Andropogon hallii
Spartina pectinata
Phleum pratense
Poa compressa

9-12: D_s=.89, HV=2.47

Panicum virgatum
Ambrosia psilostachya
Artemesia ludoviciana

9-13: D_s=.82, HV=3.36

Calamagrostis stricta
Carex aquatilis
Poa compressa

9-14: D_s=.89, HV=2.97

Spartina pectinata
Ambrosia psilostachya
Panicum virgatum
Phleum pratense

9-15: D_s=.88, HV=2.50

Panicum virgatum
Calamovilfa longifolia
Andropogon scoparius
Ambrosia psilostachya

9-16: D_s=.85, HV=2.57

Panicum virgatum
Calamovilfa longifolia
Andropogon scoparius

9-17: D_S=.81, HV=2.45

Calamovilfa longifolia
Solidago rigida
Andropogon hallii

9-1[illegible]: D_S=.84, HV=2.63

Silphium integrifolium
Panicum virgatum
Artemesia ludoviciana

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